Lab Exercise 7G Solution and Gas Stoichiometry

In this test of stoichiometry, both solution and gas calculations are needed. The reaction is related to the practical chemistry of baking (Figure 7.13). As a project, students study the reaction of baking soda (sodium hydrogen carbonate) and hydrochloric acid to produce sodium chloride, carbon dioxide, and water. Complete the Prediction of the investigation report.

Problem

What volume of carbon dioxide gas at 100 kPa and 35°C is produced by the complete reaction of 50 mL of a 0.200 mol/L baking soda solution with excess hydrochloric acid?

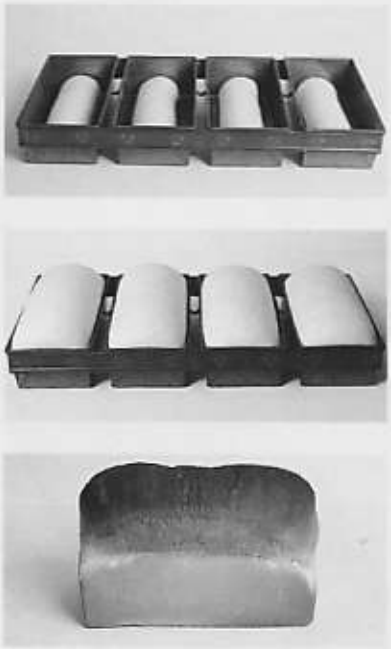

Figure 7.13
The photographs show bread dough before rising, after rising, and after baking. The rising of baked goods depends on the production of carbon dioxide gas from yeast cells, baking soda, or ammonium hydrogen carbonate.

7.5 THE SOLVAY PROCESS: A CASE STUDY

The worldwide production of glass and soap requires huge amounts of sodium carbonate, or soda ash (Figure 7.14). Until the late 1700s, the main source of sodium carbonate was burned plants; the ashes were mixed with water and the soda ash was extracted. During the 19th century in France, an industrial method called the LeBlanc process was developed for producing soda ash, but this process required burning a lot of coal, which was expensive. (It also caused considerable air pollution, but at the time this was not considered to be a problem.) In 1865 Ernest Solvay, a Belgian chemist, began to perfect the ammonia-soda process for the production of soda ash, and in 1867 Solvay's process was installed for the first time in his small factory in Belgium.

Since the LeBlanc process was so firmly established, the new Solvay process did not gain immediate acceptance. But the cost of the new process was one-third the cost of the old LeBlanc process, so Solvay processing plants were eventually built in every major industrialized country. The wide use of his invention brought Solvay a great deal of money, much of which he channelled into philanthropic work in Brussels.

The overall reaction in the Solvay process, involving calcium carbonate and sodium chloride, is one that does not occur spontaneously at room temperature.

$$CaCO_{3(s)} + 2\ NaCl_{(aq)} \rightarrow Na_2CO_{3(aq)} + CaCl_{2(aq)}$$

Imagine adding chalk to a salt solution — no reaction occurs. How then can this reaction be implemented industrially to produce large quantities of soda ash? Solvay's design involved an indirect route with a series of intermediate reactions. His major breakthrough involves a reaction that at first glance seems improbable.

$$NH_4HCO_{3(aq)} + NaCl_{(aq)} \rightarrow NH_4Cl_{(aq)} + NaHCO_{3(s)}$$

What Solvay discovered by experimentation is that in cold water ammonium chloride has a higher solubility than sodium hydrogen

Figure 7.14
The Solvay process is used in this soda ash plant. The saleable products are washing soda, baking soda, and road salt.